PROJECT PLAN PROSPECTUS
304 Crop Protection and Quarantine
November 2004 – January 2005

Old CRIS Project Number

3611-22000-017-00D

Research Management Unit

3611-25-00 – Invasive Weed Management Research

Location

Urbana, Illinois

Title

Biologically- and Ecologically-Based Knowledge for Integrated Weed Management Systems

Investigators

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Scientific Staff Years

2.90

Planned Duration

60 months

Signatures

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Key words
Ecology, Weeds, Seeds, Seed bank, Microorganisms, Environment, Herbicides, Corn, Soybean, Sweet corn, Vegetable crops, Integrated weed management

Objectives

Objective 1. Gain knowledge of the ecology of important weeds in vegetable and agronomic crops to understand the fundamental principles that affect weed emergence, growth, interference, seed production, and crop yield and quality.

Objective 2. Investigate the ecology, physiology, and biochemistry of microbial interactions with weeds or weed propagules in seed bank systems to understand natural mechanisms that can affect weed fate.

Objective 3. Identify effective combinations of weed management components through application of both new and existing knowledge and technology that exploit useful plant, microbial, and environmental interactions.

Need for Research

- *Description of Problems to be Solved –*
  1. Agroecosystems are comprised of multi-trophic interactions that occur in complex physical and chemical environments. Many of the factors involved in these interactions are not fully understood. Effective strategies for integrated weed management will require knowledge of important biotic and abiotic factors, as well as comprehensive understanding of how these factors interact within the context of the total agroecosystem. Both short- and long-term research on the biology and ecology of weeds is required for development of broad-based and sustainable weed management that is effective and minimizes negative consequences to the environment and health of humans and animals.
  2. The biology and ecology of invasive weeds must be investigated in order to understand the context and processes in which they negatively affect food production and ecosystem function, as well as the adaptive mechanisms that allow these species to succeed. Studies of competitive interactions between weeds and agronomic crops have been largely descriptive, with a recent interest in development of a mechanistic understanding of interplant competition. While crop and weed interactions are species-specific, the significance of weed competition on growth, development, yield, and quality of many vegetable crops is largely unknown. As an example, sweet corn cultivars are typically less vigorous than field corn, are locally planted and harvested over a range of dates, exhibit considerable polymorphism, and have striking cultivar-specific responses to many herbicides. Furthermore, the extent to which weed presence and/or competition influences crop maturity and overall marketability is poorly documented. Understanding the comprehensive impact of weed species in vegetable crops may require not only how weeds influence crop growth and yield, but also vegetable quality.
  3. Research is needed to understand the mechanisms that regulate the processes of weed seed bank dynamics, including myriad biotic and abiotic factors that may affect seed longevity, dormancy, and mortality. Among these are environmental and organismal factors that directly and indirectly influence natural microbial populations, the majority of which are not well characterized in soil environments, and may be key to certain mechanisms that control seed fate. Little is known about the role of soil microorganisms in seed bank dynamics, which may include loss of seed by decay, alterations to the physiological and biochemical status of seeds or seedlings, and mutual adaptations leading to microbe and seed survival. Along with identifying important microbial

populations and the activities expressed that influence seed fate, the role exerted by seeds themselves in their relationship to microorganisms, as well as each other, is poorly understood. Knowledge concerning the microbial ecology of seed banks, within the context of the ecology of the total system, is required. Advances in this area have been hampered by the lack of suitable methods for comprehensive analysis of microbial communities and their function, particularly in complex soil systems. Development of new and modified techniques is required to effectively conduct *in situ* studies on microbial populations and their interactions in seed bank systems.

4. There is a continuing need for safe, effective, and affordable herbicides to replace antiquated chemistry, which in some cases has lost efficacy or presents significant risks to the environment. There is a need to determine the suitability of safer herbicides, especially for minor crops that provide a modest economic incentive for the private sector owing to limited acreage.
5. Weed management systems that rely heavily on single techniques, such as the use of herbicides, tillage, or biological control alone, may result in the development of weed populations or communities that escape and threaten the ecosystem. Recognizing that ecosystems are dynamic, research aimed at optimizing the use of multiple mortality- and fitness-reducing events will facilitate development of integrated weed management systems. Increased research is needed on the biology and population dynamics of weeds, weed propagules, and soil microorganisms in response to newly developed crop and soil management systems. Limited options are available for managing weeds in vegetable crops, thus the larger knowledge base gained from studying corn and soybean may be beneficial for developing weed management strategies for minor crops.

- *Relevance to ARS National Program Action Plan* –
  This program falls within Component VII (Weed Biology and Ecology), Component VIII (Chemical Control of Weeds), Component IX (Biological Control of Weeds), and Component X (Weed Management Systems) of NP 304. The primary focus will be to investigate the ecology and management of important weed species in major vegetable, agronomic, and rotation crops in the Midwest. Common factors affecting these crops in regards to crop/weed interactions, weed seed bank characteristics, and weed management will be evaluated, however, factors unique only to vegetable crop systems will also be determined. A primary focus will also be to investigate the role that microbial communities have on weed seed fate and the overall crop system. The project is also tied to NP 302 (Plant Biological and Molecular Processes) Components IIb (Plant Tolerance to Environmental Stresses) and IIIc (Biological Interactions that Reduce Environmental Pollution). The project will identify the underlying principles that affect weed emergence, growth, interference, and seed production as critical components that contribute to weeds as stressors in crop systems. By also including seed bank factors, this research will address the development of improved weed management systems that emphasizes integrated non-chemical and chemical methods in crop systems to minimize harmful effects of herbicide input into the environment.
- *Potential Benefits Expected from Attaining Objectives* –
  Attaining these objectives will: 1) improve our understanding of fundamental biological and ecological factors that regulate weed invasion, 2) improve our knowledge of specific microorganism-weed target relationships and the potential for weed seed bank manipulation by enhancing specific populations and activities of native soil microorganisms, and 3) determine the effectiveness of combining new and existing knowledge and technologies for weed management that exploit useful interactions. Knowledge of key environmental and biological factors and how these might be modified or enhanced for weed management is anticipated. Data and technology transfer from this project will assist other scientists working in related areas. The major objectives of

this project are intended to be addressed over long term (20 years) and will be achieved by addressing more specific short term (5 years) subobjectives that are progressively built upon an increasing database of knowledge and technology development. The overall benefit will be long term, sustainable weed management based on the use of underlying biological and ecological principles that govern agroecosystem processes, leading to adaptable and site specific practices.

- *Anticipated Products of the Research* –
  Fundamental knowledge regarding weed biology, crop/weed ecology, microbial function and ecology, and weed seed bank ecology; characterization of physical, chemical, and biological factors affecting weed development and spread; knowledge contributing towards systematic prediction of the impact of weeds on vegetable crop yield and quality; synergistic combinations of ecologically-based weed control tactics that include herbicide use in the system.
- *Customers of the Research and Their Involvement* –
  Producers of major agronomic and vegetable crops of the Corn Belt will be included in the research process and informed of research results and products. Weed scientists, plant biologists, microbiologists, and ecologists will benefit from a stronger knowledge base. Midwest Food Processors Association, Inc. and the Illinois Soybean Program Operating Board are important stakeholders and potential sources of support. Regulators and the general public expecting safe and economical food and fiber will also benefit.

Scientific Background

1. The project is closely coordinated with the Unit's other primary CRIS project, CRIS 3611-12220-002-00D, "Factors contributing to persistence of herbicides and strategies for reducing off-target impacts", which falls within NP 202 (Soil Resource Management). Basic research findings on herbicide persistence and movement in the environment, herbicide transformation, and identification of key weed seed chemical components from the other CRIS project will be applied to elements of safe herbicide use, plant ecology, seed bank ecology, and microbial activity directed towards weed and weed seed fate in this project.
2. The project is related to the ARS Unit's CRIS 0500-00007-061-00D, "Minor Use Weed Management" in coordination with the IR-4/ARS program, where the objectives are to assess new uses of herbicides for weeds in vegetables, fruits, and specialty crops. Evaluation of herbicide use alone or in combination with non-chemical methods in vegetable crops from the project "Minor Use Weed Management" will be coordinated with the components of weed management in minor crops described this project.

Approach and Research Procedures

Objective 1.

Hypothesis – Fundamental knowledge of weed biology, crop/weed ecology, and microbial ecology of the plant-soil system will provide needed insight into improving integrated weed management.

Experimental approach – Experiments will be conducted within model study systems, which represent major vegetable and agronomic crops and associated weeds, both common and emerging species, in the Corn Belt region. Sweet corn (*Zea mays* L.) will serve as the primary vegetable crop of study and the extent to which results may apply to other regional vegetable crops is unknown. Generally, weed management decisions are guided by treatment of anticipated or actual presence of weeds, rather than systematic prediction and action based on the impact of weeds on crop yield and quality. This is particularly true of sweet corn, since little is known about the dynamics of sweet corn/weed communities. Therefore, experiments will

be designed to characterize weed species and communities in the field, with particular focus on their impact on sweet corn growth, yield, and measures of crop quality. Studies will also be targeted at a mechanistic understanding of weed seed bank dynamics, particularly as it relates to outcomes of weed emergence and growth at the field scale.

Specific research procedures – Interference experiments will be used to quantify the effects of planting date, sweet corn cultivar, and competitive load on crop/weed interactions. Specifically, experiments will be used to quantify critical weed-free periods and relationships among weed density and yield loss. The extent to which weed competition affects sweet corn maturity, ear uniformity, and individual yield components is unknown. Therefore, initial studies will be used to determine those response variables that are significantly affected and should be considered in future work. Given the large polymorphism among sweet corn phenotypes, experiments will be planned to quantify variation in canopy environment, crop tolerance, and weed suppressive ability among crop phenotypes. Outcomes from studies, repeated over multiple environments, will be used to parameterize empirical yield loss models, which collaborators may then begin building within a decision support system. Long-term agronomic experiments will allow monitoring of weed seed bank characteristics over time as it relates to biotic and abiotic factors, as well as provide conditions for *in situ* evaluation of microbial populations that may affect weed emergence.

Contingencies – Short maturity sweet corn cultivars may avoid losses due to weeds, however, yield losses are expected with longer maturity cultivars and/or under stressful environments. Sweet corn yield components (e.g. cut kernel mass) to be measured will depend upon availability of small plot processing equipment. The work related to agronomic crops will be explicitly defined upon filling the Ecologist/Plant Physiologist/Research Agronomist vacancy.

Collaborators – John Masiunas, University of Illinois; Alex Martin, University of Nebraska

Objective 2.

Hypothesis – Identifying seed bank factors and mechanisms of interactions, including contributions from microbial populations, weed or weed propagules, and the soil environment, is critical in understanding weed seed bank dynamics. Native soil microorganisms are hypothesized to significantly impact seed fate, but currently undefined factors limit these activities. Key microbial responses are likely linked to plant and environmental factors occurring in both below- and above-ground processes.

Experimental approach – Experiments will be designed to identify and characterize the important microbial populations involved in seed interactions, and to examine the specific biological and environmental factors that contribute to enhancing or detracting from these interactions. Controlled studies will be designed to investigate specific biochemical mechanisms of seed-microbe relationships, including microbial-mediated decay processes, effects on seedling development, and seed biological factors that directly affect microbial seed zone processes. Basic knowledge is stressed, however as principles become better understood, experiments that integrate the study of seed bank factors with weed-crop dynamics (Objective 1) can be developed, and we can begin to examine microbial-related seed bank modifications as a critical component of effective integrated weed management (Objective 3). A broad range of weed species important to corn (*Zea mays* L.), soybean (*Glycine max* L.), and vegetable crops will ultimately be targeted as we address our study objectives over the long term, however, we will initially focus on velvetleaf (*Abutilon theophrasti*) and giant ragweed (*Ambrosia trifida*), two annual weed species that are important in the Midwest region.

Specific research procedures – Controlled environment and field experiments will be conducted and the specific methodologies used will be scale-dependent. Traditional cultivation and physiological/biochemical testing methods will be used to screen, isolate and characterize individual soil- and seed-borne microorganisms and their activities against weeds and weed seeds. Current PCR- and probe-based methods for species identification and community

fingerprinting, and molecular-based methods coupled to microscopy will be used to identify important microbial species, characterize microbial communities in association with soil, plant, and seed surfaces, and facilitate microbial tracking. High-resolution microscopy will allow observations of fine seed structure, and the temporal/spatial dynamics of microbial associations with seeds and each other. In addition to controlled laboratory-scale studies that examine microbial effects on seeds, we plan to conduct seed burial studies under field conditions. The outcome of these procedures should yield descriptive, spatial, and quantitative data, as well as define the mechanistic details of important seed bank relationships and interactions. To address a gap in knowledge regarding seed physiology that may relate to microbial responses, we have initiated studies to characterize properties both beneficial and antagonistic to microorganisms of compounds produced by weed seeds or associated with seed components.

Contingencies – Soil and unknown seed factors can confound strategies for microbial isolation and many molecular biology methods. Suitable methodologies for *in situ* study of microorganisms are still emerging, and will be incorporated into our experimental design as needed. Additional species of seeds selected for further studies will depend on applicability and the ease of use in experimental design (e.g. seed recovery after burial). Extensive investigations into natural product chemistry of weed seeds will require expertise outside our unit and will be established as needed. The work related to agronomic crops will be more specifically defined after filling the vacant Ecologist/Plant Physiologist/Research Agronomist position.

Collaborators – Ann Kennedy, ARS, Pullman, WA; John Masiunas, University of Illinois

Objective 3.

Hypothesis – Safe, effective, and affordable weed management systems will require not only minor modifications to existing systems, but also include the judicious use and integration of new tools (both chemical and non-chemical) and new information in weed ecology.

Experimental approach – Fundamental knowledge gained from Objectives 1 and 2 will guide development of improved, integrated weed management systems for vegetable crops and agronomic crops. An approach combining lower-risk, shorter-term strategies will be examined in conjunction with higher-risk, longer-term weed management tools for the future. Short-term approaches will include the investigation of newer, safer herbicides to reduce the use of outdated or environmentally risky chemistry. Investigations of potentially viable herbicide agents for vegetables will be coordinated with the IR-4/ARS Minor Use Herbicide Program. Intermediate- and longer-term management systems may include also the use of new knowledge of weed and microbial ecology, genetically modified crops, biological control candidates, seed bank management, and mechanical and cultural approaches, depending upon development and availability of such technologies.

Specific research procedures – Traditional field and controlled-environment experimentation will be used to assess both the role of weed management components and a combined systems approach. In some cases, herbicide carryover potential and environmental impact will be assessed using radiolabeled tracers, if available. Alternatives to triazine- and chloroacetamide-based weed management programs will be considered. Practicality of weed management components and systems will be determined based on parameters of weed and crop fitness. Shifts in important microbial populations will be monitored as they relate to the fate of weeds or weed seeds.

Contingencies – Investigation of specific chemical and non-chemical weed management components will depend upon availability. Herbicide fate studies will depend on the availability of isotopically labeled compounds through commercial or manufacturer-supplied sources. Microbial analyses will depend on the methodological limitations attributed to soil heterogeneity. The work related to agronomic crops will be explicitly defined upon filling the vacant Ecologist/Plant Physiologist/Research Agronomist position.

Collaborators – John Masiunas, University of Illinois